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FACTORS AFFECTING PHYTOTOXICITY OF NAPHTHAS FOR WEED CONTROL IN COTTON[1]

J. T. Holstun, Jr., and C. G. McWhorter

Herbicidal naphthas were first recommended for weed control in cotton in 1950 (11).[2] Use of these materials has fluctuated widely but generally has tended to increase, particularly in recent years. A survey by the Mississippi Agricultural Extension Service indicated that approximately one-third of the cotton grown in the Delta of Mississippi was treated postemergence with herbicidal naphtha in 1963. Similar or higher proportions of the cotton acreage have probably been treated in Missouri, Arkansas, Louisiana, and Texas. Use of naphthas for weed control in cotton in other States, while on a smaller scale, is significant. Usage of herbicidal naphtha has continued to increase, because these materials provide safe, effective, and economical control of many weeds in cotton. Current information concerning instructions for use and limitations for naphthas for weed control in cotton is available in all the cotton growing areas.

The development of naphthas for weed control in cotton resulted from experimentation in field plots supported by limited greenhouse and laboratory research. Controlled field experiments are still required for reliable evaluation of a specific naphtha, method of use, and practical applications of related physiological principles. The primary purpose of this report is to present general information of value in the preparation of herbicidal naphthas for cotton and in the preparation of instructions for use of these products. This information is intended to be used only as a guide for preparing products for field evaluation, and not as exact specifications that will necessarily result in the preparation of a satisfactory product.

BASIS OF REPORT

Greenhouse and field experiments at the Delta Branch Experiment Station, Stoneville, Miss. and published data as cited provides the basis for this report. Several companies, basic in petroleum products, supplied samples of naphtha, typical specifications, and data on sample analyses for the experiments. Field and greenhouse experiments have been conducted over an approximate 15-year period to study:

1. Weed control and cotton tolerance to herbicidal naphthas as affected by various nozzle settings, arrangements, and combinations.

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[1] Cooperative investigations of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the Mississippi Agricultural Experiment Station.

[2] Underscored figures in parentheses refer to Literature Cited at end of publication.

2. Weed control and cotton tolerance as affected by the number of applications throughout the growing season.

3. The effect of number of cotton plants per hill on cotton tolerance to various types of naphtha.

4. The effect of various rates of naphtha on cotton tolerance as affected by dates and combinations of dates.

5. The susceptibility and resistance of various cotton species and varieties to herbicidal naphthas.

6. The efficiency of several preemergence herbicides and postemergence naphtha treatments applied singly and in combination for weed control in cotton.

7. The general efficiency of naphtha applications as affected by the type of nozzle tip used in application.

8. Changes in tolerance of cotton to herbicidal naphthas as affected by soil moisture and other environmental conditions.

Much of the above-listed research was conducted with naphthas of different chemical composition and from different sources. Crop and weed responses to treatments were recorded by the use of several agronomically acceptable techniques. Several experiments were conducted specifically to study the effect of physical and chemical properties of naphthas on cotton and weed response. Owing to the general nature of discussion to follow, specific data from this research will not be presented, but those data not cited in the bibliography are available in annual reports of the Weed Control Project, Delta Branch Experiment Station, Stoneville, Mississippi.

FACTORS THAT AFFECT PHYTOTOXICITY

The selective control of weeds in cotton with herbicidal naphthas depends on an extremely complex combination of factors. These factors include method of application, inherent and induced properties of the plants, chemical and physical properties of the naphtha, and contamination of the naphtha with other materials.

1. Method of application. Correct placement through directional spraying is one of the most important factors contributing to selective phytotoxicity. Only the naphtha-tolerant cotton hypocotyl should be contacted by the spray (fig. 1), while weeds are either completely covered by the spray or susceptible parts of the weed are contacted. If the orifices of the B nozzles of figure 1 are larger than those of the A nozzles, less naphtha will be applied in the drill row than on the row shoulders.

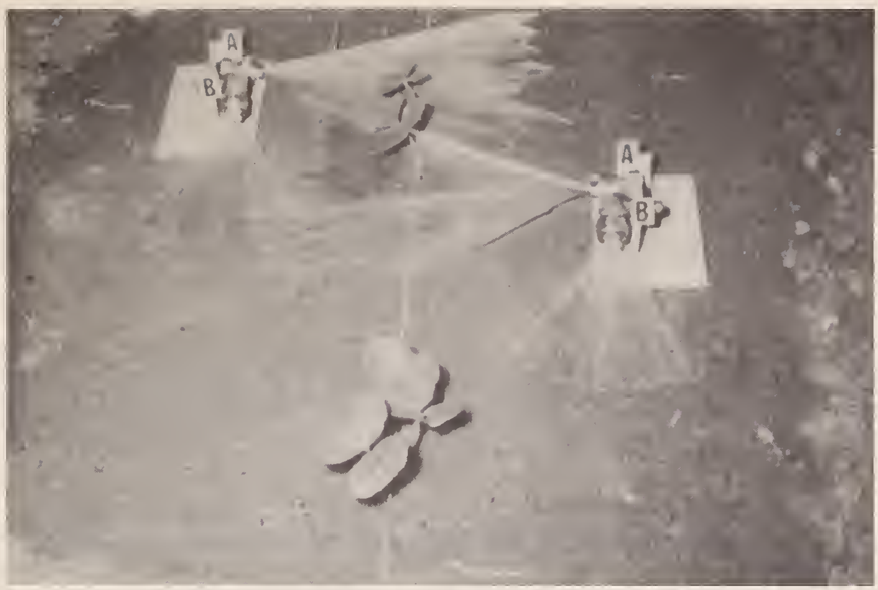

Figure 1. Nozzle setting for spraying herbicidal naphtha. Front nozzles (A) are spraying across the row, while rear nozzles (B) are spraying rearward and down. This combination of nozzles produces 12 to 14 inches of coverage.

This unequal distribution of a fixed rate of naphtha makes it possible to apply simultaneously a rate in the drill row that the cotton will tolerate and a higher rate for better weed control on the row shoulders. The 4-nozzle arrangement shown in figure 1 resulted from more than a decade of research (4, 5, 11).3/

Shape, smoothness, and uniformity of the row are critical in placement of the naphtha. The ideal row is about 2 to 3 inches high and level for about 9 inches on each side of the drill row, uniform in height and width, and free of clods and other obstructions. Deviations from these ideal row characteristics may result in placement of the naphtha on susceptible parts of the cotton and in poor coverage of the weeds.

2. Inherent and induced plant properties. Cotton in the seedling stage is relatively tall as compared with many seedling weeds. This size difference permits complete coverage of the weed with a naphtha application that contacts

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3/ Wooten, O. B., and Holstun, J. T., Jr. Development of equipment for postemergence weed control in cotton. Paper presented at 1963 winter meeting of the American Society of Agriculture Engineers, Chicago, Illinois, December 10-13, 1963.

only a part of the cotton plant. Repetitive killing of weeds in the seedling stage coupled with survival and growth of the cotton increases the height ratio of cotton to weeds as the season progresses. This increase in safety through increased height, however, is largely offset by a corresponding decrease with age in the resistance of the cotton hypocotyl to the naphtha (7, 8, 9). Between 3 and 6 weeks after emergence, tiny cracks appear in the epidermis of the cotton, and during this period, the hypocotyl becomes susceptible to naphtha injury (7, 8, 9). All grasses and many broadleaf weeds, on the other hand, tend to become more difficult to kill with naphtha as they age.

The differences in the anatomy of the cotton plant and various weeds interact with other factors to influence herbicidal selectivity. The growing points of most plants are very susceptible to the naphtha. If all growing points of a plant are killed, the plant either dies or fails to grow. Foliar-growing points of cotton are well above the area of application within 3 to 7 days after emergence. The growing points of many weeds, particularly annual grasses, remain near the ground for a much longer period. The foliar growth zone of nutsedge, although below the ground, can still be contacted by a proper application of naphtha. The leaves of the nutsedge plant join at their base to form a funnel which leads directly to the underground tuber and the growth zone of the leaves. A proper application places naphtha in this funnel for penetration down to the tuber, and further growth of this weed is delayed until a new shoot develops from the original or an adjoining tuber. The hypocotyls of some broadleaf weeds such as pigweed, cocklebur, sida, and others are somewhat resistant to the naphtha, and these weeds must be sprayed before the growing points grow above the area of spray application.

The effects of weather on the response of plants to naphtha are many and complex. Other factors being equal, naphtha is more phytotoxic during hot, dry days than in cool, moist days. Plants grown completely in hot, dry weather, however, are more tolerant to the naphtha than those grown under conditions of optimum growth. The fundamental basis for these responses is poorly defined. In general, however, the influence of weather is not extremely critical except for two conditions that may increase cotton susceptibility. First, cotton of any age should not be treated with naphtha while the soil is too wet for cultivation if the temperature is above 85° F. Second, cotton released by rain or irrigation from drought stress of more than 2 weeks' duration is very susceptible to naphtha and should not be treated. Both conditions probably result from an abruptly accelerated rate of cotton growth, which intensifies ruptures in the protective epidermis of the hypocotyl.

Only young, healthy hypocotyls of cotton are tolerant to naphtha. Cotton plants with hypocotyls that have been damaged by disease or mechanical injury may be killed by naphtha. Naphtha should not be applied in fields of diseased or mechanically damaged cotton unless the number of healthy plants is sufficient to provide an adequate stand in the event that all unhealthy plants are killed.

Differences among varieties of the one species of cotton commonly grown in this country and among certain other species of cotton in the response to naphtha have been reported (5). Differences among the commercial varieties, however, were apparent only when excessive rates of naphtha were used. Most of the currently grown varieties appear to have sufficient tolerance to permit the use of naphtha within the current limitations. Certain Asiatic species of cotton appear highly tolerant to naphthas, but attempts to incorporate this tolerance into commercial upland varieties have not been reported.

3. Chemical and Physical Properties of the Naphthas. Chemical composition and physical properties of herbicidal naphtha constitute highly critical factors in the performance of the product. The evaluation of many products in the early 1950's yielded only limited fundamental information concerning these factors (4, 5, 6, 7, 10, 11).

Chemical composition of currently available naphthas is fixed partly by the refining process used in preparation of the product. Also, the composition can be varied through blending of a base product with other materials. For example, a product that is safe on cotton and ineffective on weeds may be made satisfactory by blending with pure aromatics. Such a blend should not be marketed, however, until field evaluation has demonstrated that the blend is both safe on cotton and effective against weeds.

Source of crude oil is a factor that determines the chemical composition of herbicidal naphthas. Herbicidal naphthas obtained by using identical refining processes on crudes from different geographical areas may be expected to differ in performance, even though the general specifications for the two products are similar. There is no published information concerning the identification of specific compounds in the herbicidal naphthas now being used for weed control in cotton. A complete analysis of a nonblended product would be very expensive and probably impractical, regardless of the cost. It is doubtful that any commercial naphtha now being sold for weed control in cotton results from blending of pure individual compounds in known proportions. Thus, reference to aromatics, naphthenes, and paraffins is generally in terms of broad classes of materials, and not specific compounds.

Data from field and greenhouse experiments at the Delta Branch Experiment Station and other research as cited indicate that several generalizations in regard to specifications for naphthas for weed control in cotton can be made. The principal components in each of the products evaluated thus far are aromatic, naphthenic, and paraffinic hydrocarbons. Other compounds present were considered as undesirable impurities. The aromatic group is considered the primary phytotoxin, naphthenes secondary, while paraffins are the least phytotoxic (1, 2, 3, 5, 12).

The lighter aromatics, such as those found in present naphthas for cotton, cause acute injury to plants, whereas the higher boiling aromatics tend to cause chronic toxicity (1). Chronic phytotoxicity is undesirable for naphthas used for weed control in cotton. Most satisfactory products contain a minimum of 14 percent aromatics and not over 24 percent. Naphthene content in most of the satisfactory naphthas ranges from 14 to 35 percent. Naphthene concentrations that are too high may cause limber stems in the cotton (5, 10, 11). If aromatic content is high, than naphthene content should be low or vice versa.

Paraffins appear to serve more as a diluent for aromatics and naphthenes than as a phytotoxin. Paraffins do, however, have some phytotoxicity, particularly those with carbon chains shorter than 10 atoms (12). Paraffin content in most satisfactory products ranges from approximately 49 to 60 percent (98 percent less the percentage of aromatics and naphthenes).

Straight chain unsaturates, unsaturated cyclic compounds other than aromatics, and any compounds containing elements other than hydrogen and carbon have not been investigated extensively for the control of weeds in cotton under field conditions. Satisfactory materials usually contain less than 2 percent of these compounds.

Nonvolatile components should not be present. Trace amounts of these materials may greatly increase toxicity to cotton. Nonpetroleum herbicides should not be added as fortifying agents without exhaustive investigations. All fortified naphthas evaluated to date have caused excessive cotton injury.

Boiling range is very important in balancing weed control and crop tolerance (11). Continuous distillation of a crude oil permits separation of desirable fractions that have a common boiling range from undesirable fractions boiling in either higher or lower ranges. Most satisfactory products have a boiling range approximating the following:

Initial boiling point - - - - - - - - - - 300°F.

50 percent recovery point - - - - - - - - 340°F.

End point - - - - - - - - - - - - - - - - - - 400°F.

Materials with lower boiling ranges tend to evaporate too rapidly so that weed control is ineffective. Materials in which the end point greatly exceeds 400°F. usually cause chronic cotton injury.

Viscosity is probably an important factor, but has not been extensively studied. A viscosity of about 1.3 centistokes was reported for some satisfactory products.

Gravity is not known to be critical, although most satisfactory products have a gravity rating of 40° to 54° API.

Fulfillment of the above specifications may not necessarily insure a satisfactory product, but failure to meet these specifications does not necessarily imply that a product will fail to be satisfactory. Use of these specifications should, however, facilitate the selection of a narrow range of products for field evaluation.

The greatest hazard in the use of herbicidal naphthas arises from the second, third, or later applications. Under ideal conditions, cotton can tolerate, with only moderate injury, at least one application when the cotton is 2 to 3 inches tall plus four additional applications at weekly intervals at rates 40 percent above the recommended rate. This margin of safety is needed to offset normal variations in cotton development and vigor or other variations in normal usage. Such safety margins should not be used to promote sales since this could lead to disastrous results under conditions that are not ideal.

4. Contaminants, chemical changes, and heat effects. A high quality product can be made unfit for use by contamination or chemical changes during transportation, storage, and application. Contamination of herbicidal naphtha with even small amounts of motor oils, diesel fuels, greases, kerosenes, waxes, or nonpetroleum chemicals may result in serious cotton injury. Generally tanks that are normally used for transportation or storage of herbicidal naphthas should not be used for transportation or storage of any chemical that is difficult to remove. For instance, a tank used to transport diesel fuel or gasoline can be easily cleaned by several rinses with small amounts of naphtha, whereas a tank used for transport of pentachlorophenol would be very difficult to clean. In any event, cleaning of tanks should consist of thorough washing with a good solvent followed by several rinses with small amounts of naphtha. Naphtha will often serve as an adequate solvent and for rinsing.

All hoses that are contacted by herbicidal naphtha should be of an oil-resistant type. Furthermore, the naphtha remaining in any hose from previous use should always be discarded. Naphtha may dissolve harmful chemicals from some types of hose if allowed to remain in contact for long periods.

Storage tanks should exclude all light and should be kept as full as practical to reduce oxidation and selective evaporation. Oxidation may result in the formation of highly phytotoxic acids and other chemical changes. Evaporation from open or partially filled tanks may result in loss of the lighter fractions so that composition could change materially with time.

Spray machines for application of herbicidal naphthas should be thoroughly cleaned of previous materials before use. Damage resulting from improper cleaning of spray machine tanks usually becomes less severe as the tank is emptied and refilled. Even so, extensive cotton acreage can be damaged with one sprayer load of naphtha. Only pumps with sealed bearings should be used on spray machines applying herbicidal naphthas. Grease applied through nonsealed fittings is quickly dissolved by the naphtha resulting in increased phytotoxicity from the naphtha. Excessive bypassing of the naphtha may increase the temperature of the naphtha to the extent that the phytotoxicity is materially increased. Since herbicidal naphtha does not require agitation, the pump used in application should not be of more capacity than that needed to maintain the desired pressure.

Because of the temperature effect on phytotoxicity, the exterior of storage and spray tanks should be white rather than dark. Filled spray machines should be parked in the shade when not in operation.

SUMMARY

Herbicidal naphthas make a major contribution to the control of weeds in cotton. Laboratory, greenhouse, and field plot research over a wide geographic area has provided data that are helpful in studying the factors which influence the phytotoxicity and selectivity of naphthas used for weed control in cotton.

These studies indicate that the consideration most likely to lead to the successful selective control of weeds in cotton with naphtha are as follows:

1. Place spray to avoid contact with susceptible parts of the cotton plant.
2. Time applications so that weeds are smaller than the cotton when treated.
3. Limit applications to an early period when cotton is in a tolerant stage of growth.
4. Avoid applications when cotton is in certain abruptly accelerating stages of growth, or when cotton has been injured mechanically or by disease.
5. Select naphthas in which certain chemical and physical specifications are approximately as follows:

    a. Aromatic content - - - - - - - - - - - - - 14 to 24 percent
    b. Naphthene content - - - - - - - - - - - - 14 to 35 percent
    c. Paraffin content - - - - - - - - - - - - - 49 to 60 percent
    d. Other volatile petroleum products - - 0 to 2 percent
    e. Initial boiling point - - - - - - - - - 300°F.
    50 percent recovery point - - - - - - 340°F.
    End point - - - - - - - - - - - - - - - - 400°F.
    f. Gravity - - - - - - - - - - - - - - - - - 48°API
    g. Viscosity - - - - - - - - - - - - - - - - 1.3 centistokes

6. Use transportation, storage, and application methods that minimize chemical and physical changes in the naphtha and contamination with other chemicals.

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